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United States Wind Energy Growth and Policy Framework

Preprint

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UNITED STATES WIND ENERGY GROWTH AND POLICY FRAMEWORK

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ABSTRACT: Wind is the fastest growing source for electricity in the United States. During 2001, U.S. wind power plant installations are expected to increase by 1,850 megawatts (MW), resulting in a total installed capacity of about 4,400 MW. The market expansion is supported by a variety of Federal and state incentives in the form of production tax credits, renewable energy production incentives, renewable energy portfolio standards, and others. New mechanisms include green power offerings, green tags, and government power purchases. Deregulation of the electric power industry is continuing. In some cases this is allowing higher electricity rates that may increase the rate of wind plant development. Power shortages, natural gas price increases, and enforcement of clean air laws are increasingly important wind market drivers in some regions. Continuing research and technology development has reduced wind energy costs dramatically to less than $0.04/kWh for large projects at sites with average wind speeds higher than 7.0 m/s, making wind the least-cost option in some power markets. The recently published National Energy Policy contains recommendations to increase wind energy development and improve the power transmission system.
Keywords: National/International, R&D, UNITED STATES

1. EXPANDING WIND POWER MARKETS

In the United States, wind power plant installations are expanding rapidly in many parts of the country. At the end of year 2000, the installed U.S. wind capacity totaled 2,554 megawatts (MW). Many new projects are under construction, and the installed capacity is expected to nearly double by 31 December 2001. Five states are projected to add more than 100 MW capacity. The five states and their total projected capacities are: Kansas, 110.4 MW; Minnesota, 527.3 MW; Texas, 1,078.3 MW; Washington, 197.3 MW; and Oregon, 149.4 MW. Eleven states will add more than 20 MW of wind power capacity. The state of Texas will see the fastest growth with capacity expected to exceed 1000 MW (Figure 1).

Wind turbines and wind power plants are also growing in size. Several multi-year projects, with total capacity in excess of 300 MW, are planned in the states of Washington and Nevada. Many of the larger projects will employ over 1 MW turbines.

Markets for small and intermediate-size wind turbines are also growing rapidly. As acceptance of wind energy spreads, isolated communities with diesel-engine-based power systems are finding wind to be an economically competitive energy source. A project using 10 Atlantic Orient 50 kW turbines has operated successfully for more than two years in Kotzebue, Alaska (2). Sales of machines less than 10 kW are at the highest levels ever. With their proven reliability in routine operations, these small machines are installed in many grid-connected and off-grid applications. Distributed generation employing individual grid-connected turbines in a wide size range is expected to grow and could account for 20% or more of the market in the next 10–12 years [1].

Figure 1. A wind plant in west Texas powered by Enron 550-kW turbines.

2. REGIONAL INITIATIVES DIFFER WIDELY

U.S. wind market growth is driven by a variety of factors. Regional factors include: increasing demand for electricity, state and local financial incentives, concern about conventional fuel prices and generation, water shortages for hydropower, regulatory status, transmission capacity and regional operational policies, environmental concerns, and others.

In the state of California there is a growing demand for electricity and increasing generating capacity short fall, but wholesale power price limitations make it currently unattractive to install new wind plants. A near-term market for wind is not expected to develop until wholesale power pricing and other regulatory issues are resolved. However, many good wind sites in the state have excellent correlation between the diurnal wind patterns and the peak demand for electricity. Peak winds at many sites occur in later afternoon when air-conditioning loads are highest. Forty megawatts (MW) in new installations are expected during the last six months of this year with potential for additional 500 to 1,000 MW after state power economic issues are resolved.

In the Northwest, weather patterns have caused water shortages, especially in the states of Washington and Oregon. There is increasing concern about maintaining adequate river water flow for the salmon

Figure 2. A 0.5 MW hybrid wind plant in Kotzebue, Alaska, provides power for a remote village.

fishing industry, agricultural irrigation, and hydropower generation. There is also strong public demand for protecting the environment and developing green energy sources. These factors, combined with well documented, excellent wind resources, make this a high-growth region. Nearly 200 MW of wind power plants are expected to come online in Washington during the next six months.

In the Great Plains region, wind is becoming a new and important factor in rural economic development. Midwestern states from North Dakota on the Canadian border to Texas on the southern border are legendary for their high winds. Farmers and ranchers are learning how they can harness these winds to produce electricity. Energy production, using utility-scale wind turbines, can provide more consistent revenues that exceed other farm products, yet it requires less than 3% of the land area and is compatible with conventional agricultural operations. Growth in wind power in this region is also being fostered by state energy policies. Minnesota requires utilities to build wind plants as a condition for allowing additional storage of spent nuclear waste from nuclear power plants. Iowa requires its utilities to add renewables and expects to exceed legislated requirements by adding 80 MW of wind power in the next six months. Texas had developed a Renewable Energy Portfolio Standard (RPS) and is ahead in achieving its goal of adding 2,000 MW of renewable energy technologies by 2009.

3. NATIONAL ENERGY POLICY

The recently released National Energy Policy [2] contains 26 recommendations to help diversify the national energy supply, move toward clean affordable energy sources, and modernize the electricity grid and infrastructure. Most importantly, the Policy proposes a five-year extension for the wind energy production tax credit that expires 31 December 2001. The Policy also proposes expansion of performance-based research and development focused on next generation technologies, and a review of Federal land use rules aimed at streamlining approval procedures and easing access limitations for building wind power plants. Other provisions in the document that could benefit wind power development include working with regional organizations to enhance public awareness of energy issues and increase private power purchases for clean energy sources.

4. MARKET STIMULATION AND INCENTIVE MECHANISMS

The pace toward deregulation of the electric power industry in the United States has been affected by the California situation, but generally deregulation has encouraged the development of a complex and innovative array of state and Federal incentives for wind development. Often the incentives are complementary and can work together to increase leveraging effects. Many of the new competitive energy markets with more than 20 different policy approaches and variations were analyzed in reports by the National Wind Coordinating Committee (NWCC) [3 and 4].

In the United States most of electricity industry policy and pricing is controlled at the state-level by public utility commissions. As a result, individual state policies and incentives are having an increasing influence on the regional development of wind power. Many of these innovative programs are working, but the most effective are those which feature:

- Clearly defined goals,
- Long-term (typically 10 year) incentives, and
- Freedom for suppliers and consumers to choose among the various renewable energy technologies.

One successful incentive is the Federal Wind Energy Production Tax Credit. This incentive provides new wind plant owners with a tax credit of \$0.017/kWh over a 10-year period (indexed to inflation) for energy produced from wind and several other renewable energy sources. The new plants must be brought online prior to 31 December 2001. This important incentive has been one of the key drivers for the recent surge in wind plant development. Extension discussions are focused on maintaining or increasing the energy production credit and possibly expanding its use to biomass energy applications.

The Renewable Energy Production Incentive is another successful Federal incentive for municipal utilities that do not pay Federal taxes. This incentive is similar to the tax credit above. Applicants can receive a payment from DOE of \$0.017/kWh for wind energy production over a 10-year period (indexed to inflation) for plants brought online prior to 31 December 2001.

Table 1: New Renewables Capacity from Green Pricing Programs for Utilities [5]

Source	kW in place at end of 2000	%	kW planned for 2001	%
Wind	57,315	76.5	157,230	76.6
Solar	3,445	4.6	4,038	2.0
Biomass	13,690	18.3	43,300	21.1
Small Hydro	500	0.7	750	0.4
Total	74,950	100.0	205,320	100.0

On the state level, Green Power Purchasing Programs have been very successful. An increasing number of states are offering their residential and commercial customers an option to purchase electricity produced from environmentally friendly sources at a premium price. Typically, a small premium is paid for green power, depending on the renewable resource and on the supplier. For wind power the premium is as low as $0.01/kWh, with an average of approximately $0.025/kWh for all renewable technologies. Many companies that are large power consumers are embracing renewable energy purchases as a hedge against increasing natural gas prices. One consortium, called the Green Power Market Development Group, is working to develop 1,000 MW of new renewable energy capacity. Companies in this consortium include DuPont, General Motors, IBM, Interface, Johnson & Johnson, Kinko's, and Pitney Bowes. Table 1 shows the technology market shares for green power purchased through programs operated by utilities. In a similar analysis on private (non-utility) green power programs, wind captured 92% of the market.

Where green power purchasing is not available, consumers may be able to purchase renewable energy credits or "green tags." Green tags are being implemented in several states, including Pennsylvania, and by the Federal government. In a green tag transaction, the customer continues to purchase energy from its existing utility or power marketer and purchases green tags from a different supplier. Tag purchasers may be power consumers that want to support the environmental attributes of renewable energy generation or others interested in the future value of the green tags. The supplier of the "green tag" receives the premium payment once the renewable energy is sold to the local power pool at market price.

Some states are implementing Renewable Energy Portfolio Standards that require a portion of the energy sold by utilities to come from renewables. The Texas Renewable Energy Portfolio Standard requires power producers to include renewable energy sources in their generation mix and that 2000 MW of new renewable energy systems be installed by 2009. Suppliers not meeting these standards are required to pay penalties ($0.05/kWh on the shortage or 200% of the average cost of credits traded during the year), and suppliers with excess renewable energy can trade with others that are short. This Renewable Credits Trading Program starts 1 January 2002, and continues through 2019.

Several eastern states have implemented systems benefit charges for collecting a small fee, typically less than $0.001/kWh on all electricity sold in the state. These fees are used for funding renewable energy and energy efficiency programs.

The economic effects of the various state and Federal incentives are critically important to the acceleration of wind energy use. A comparison of the economic effects of the various incentives is shown in Figure 3.

5. OTHER MARKET DRIVERS

In addition to financial incentives, there are important technical and economic considerations that drive and in some cases delay wind energy market development. Some of these drivers are state-based and others are regional in nature. The following is a discussion of the key drivers affecting the wind energy market in the United States.

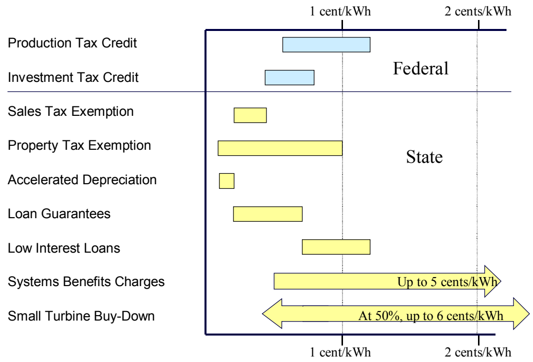


Figure 3. Renewables Incentives: Effect on COE

5.1 Conventional Fuel Costs

The price of conventional fuels, specifically oil and natural gas, is another driver for wind energy development. In 1972, 16% of U.S. electricity came from oil-fired generation. Utilities have since shifted away from use of oil as a fuel because of large price fluctuations and environmental concerns. Today less than 2% of U.S. electricity comes from oil. The share of natural gas generation has increased dramatically in recent years, averaging nearly 11% annual growth from 1996 to 2000 [6]. This increase was a result of historically low prices and lower emissions compared to coal. In 1999, natural gas provided about 16% of U.S. electricity. However, recent price fluctuations have refocused attention on balancing natural gas use with alternative energy options. The relationship between oil and gas prices and events in the wind energy program are shown in Figure 4.

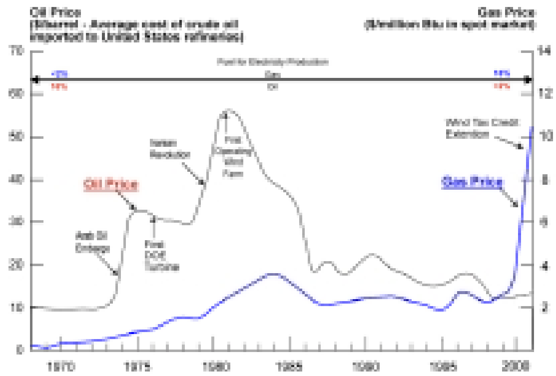


Figure 4. Oil and Gas Price

5.2 Wind/hydro Synergism

Power producers in several U.S. regions are discovering the complementary nature of using existing hydropower in conjunction with wind power plants. Water shortages in these regions are frequently forcing hydro plants to operate with reduced output due to lower water levels. The plants currently provide electricity at very low prices, but those prices depend on water supplies. Operating these plants in conjunction with wind can serve as energy storage. In the Northeast, a study is underway in Vermont to examine the economic benefits and power transmission system limitations associated with using regional hydropower in conjunction with a very high penetration of wind and biomass power plants.

5.3 Rural Economic Development

Most of the wind projects in the United States are developed on privately owned land. In addition, much of the country's strongest wind resources blow over private land located in the farming and ranching region of the Great Plains.

Farm and ranch owners in the United States are finding it profitable to harvest the wind along with other crops. One Midwest farmer leases land to a developer for three 750-kW turbines. The machines occupy about 1.3 acres, including access roads, of his 100-acre farm. In return, the farmer receives $750 per year per turbine plus 2% of energy sales for a total income of about $6,000 per year. Overall, distributed power generation can be good business for many farmers, and is a market that is expected to grow.

5.4 Federal Government Power Purchases

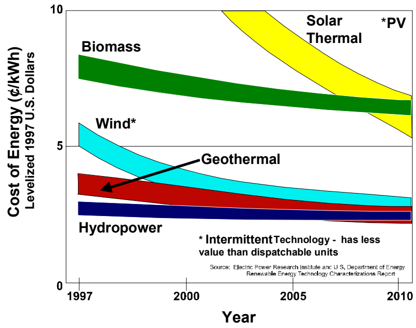
The U.S. Government is the largest single energy user in the country, spending over $4 billion annually on electricity alone. When combined with state and local governments, the public sector represents a tremendous market opportunity for renewable-generated power and equipment purchases. Within the past few years, the Federal government has been given several directives to increase its use of renewable energy. In one pilot case developed in Denver, Colorado, more than 30 Federal agencies aggregated to purchase 10 MW of wind power from the local utility's wind plant. The combined electricity demand will require additional capacity to be added to the 21 MW wind plant. This activity is currently being considered for replication across the country on Federal, state, and county levels. Finally, the Federal sector is exploring a pilot program to purchase renewable energy credits for facilities, especially in areas that do not have direct access to renewable energy resources or renewable generated power on the grid.

5.5 Clean Air Act Enforcement

The Clean Air Act Amendments of 1990 established a regulatory framework and criteria for limiting pollutants from car, power plants, and other sources. As a result many utilities switched their plants to run on natural gas. However, rising prices for natural gas are causing utilities to look toward other low-emission options, such as wind for electricity generation.

5.6 Cost Trends

Since 1980, the cost of electricity from wind systems at good wind sites without subsidies has been reduced from $0.35/kilowatt-hour (kWh) to between $0.04 and $0.06/kWh. Although costs have decreased significantly, researchers believe that further improvements could reduce costs an additional 30% to 50%. The DOE Wind Energy Program's goal is to advance the science and technology so that utility-scale, grid-connected wind power systems can produce electricity for $0.03/kWh at excellent wind sites by 2004, and for $0.03–$0.04/kWh at more moderate wind sites by 2007–2015. These projections are based on results from the DOE-Electric Power Research Institute (DOE/EPRI) assessment, *Renewable Energy Technology Characterizations* [7], and other data from commercial projects (Figure 5). Turbine installations are currently estimated to cost between $850 and $1,220/kW including both the turbines and electrical system interconnection and substation cost. The report is available on the DOE Office of Power Technologies web site at http://www.eren.doe.gov.



Report on *Renewable Energy Technology Characterizations* Available from: Electric Power Research Institute or www. eren .doe.gov/ utilities/techchar.html

Figure 5. Renewable energy cost trends

5.7 Currency Exchange Rates

Lower wind energy prices in the United States are possible due to currency exchange rates (for example $/DKK) and because of the export waiver from Value Added Tax (VAT) outside the European Union.

5.8 Transmission System

Electric power transmission system issues are becoming a barrier to wind energy development in some regions. There are many issues involved in connecting large wind power plants to the existing transmission system. Electrical interconnection, switching, control, capacity and access issues have traditional solutions in the transmission business. New and possibly more difficult issues relate to priorities in congestion management, pricing policies for new energy sources, allocation of ancillary services costs, interregional coordination, and prioritization and planning for transmission system upgrade and expansion.

6. CONTINUING R&D IS KEY

The DOE Wind Energy Program supports research and development that expands the knowledge base and improves technology leading to higher turbine performance and reliability at lower costs. [8]

Research and development efforts are focused at the National Renewable Energy Laboratory's (NREL's) National Wind Technology Center (NWTC), in Golden, Colorado, with support from the Sandia National Laboratories in Albuquerque, New Mexico. The NWTC staff conduct research and wind turbine system and component certification testing at their state-of-the-art facilities. Both Sandia and the NWTC also conduct contracted research, development, and testing for DOE and U.S. industry.

DOE's Wind Energy Program funding for the current Fiscal Year 2001 is $40 million for three areas of research; Applied Research, Turbine Research, and Cooperative Research and Testing.

6.1 Applied Research

Applied research is focused on wind energy engineering and technology issues with a broad range of scientific studies conducted at the national laboratories, universities, and in industry. This effort is aimed at improving the understanding of wind characteristics, atmospheric physics, wind turbine structural dynamics, rotor aerodynamics, and electric power system integration issues.

Aerodynamics research and design code validation places emphasis on improving energy capture from the wind and predicting the aeroelastically induced structural loads. A series of key experiments were recently conducted by NREL in a wind tunnel at the National Aeronautics and Space Administration (NASA) Ames Laboratory in California. A 30 foot diameter 20 kW experimental wind turbine was tested in different configurations in the 80 x 120 foot section of the open throat wind tunnel in June 2000. The NASA tunnel (Figure 6) is normally used for testing full-scale models of sub-sonic aircraft.

Figure 6. NREL's 20 kW experimental turbine at the NASA Ames wind tunnel.

Aerodynamic research groups from around the world were invited to participate in a "blind comparison" of the NREL/NASA tunnel test results to verify load prediction capabilities of various aerodynamics computer models. Research teams involving 30 individuals from 18 organizations (12 European) generated performance predictions using different models of the experimental wind turbine. Participants were surprised by preliminary results indicating substantial differences between various codes, and especially by some significant deviations from measured wind tunnel test results. More disconcerting was the scatter evident under supposedly easy-to-predict typical turbine operating conditions (e.g. no-yaw, steady state, attached-flow) for which power predictions ranged from 25% to 175% of measured values, and blade bending from 85% to 150% of measured values. Results are still being analyzed and consideration is being given to possibly continuing the collaboration under an International Energy Agency (IEA) Task to better understand the sources of the differences and to improve the accuracy of the code predictions.

Another element of the DOE Applied Research area is a joint research task underway between NREL and Sandia Laboratories, called the Long-term Inflow and Structural Test (LIST) Project to test effects of atmospheric turbulence and wind shear on blade structures and turbine components. Key research is focused on understanding wind turbulence effects in the nocturnal atmospheric boundary layer up to 200 m. Previous measurements have shown that turbulence-induced loads on wind turbines are strongly diurnal, the highest loads often seen during the day-night transition of the boundary layer. Comprehensive measurements are planned on two full-scale turbine rotors, in an effort to relate types of atmospheric events to structural fatigue damage. These studies could lead to increased turbine output by using taller towers to reach the more energetic winds. In addition, comprehensive measurements are planned on two full-scale turbine rotors, in an effort to relate types of atmospheric events to structural fatigue damage.

In 1999, DOE began Wind Partnerships for Advanced Component Technologies (WindPACT) as part of its Applied Research to support development of new high-risk technologies. Current studies are focused on advanced flexible rotors and new drivetrains, and on better methods for manufacturing, transporting, and installing wind turbines. Preliminary results of this research at the national laboratories and by several teams of contractors will be completed during 2001. The most promising concepts will be selected for component fabrication and operational testing.

NWTC also supports industry in developing and validating innovative wind hybrid systems that incorporate wind energy, solar cells, fuel cells, and diesel or gas generators into power systems that can serve areas with small, isolated communities. The center's hybrid-power test bed can simulate loads and connect or disconnect storage and various generators on command.

6.2 Turbine Research

DOE's Turbine Research activity provides an opportunity for U.S. industry to apply new technologies and design tools in developing advanced wind turbines. This research is conducted through close partnerships between the Wind Program's national laboratories and U.S. companies through competitively awarded, cost-shared turbine development subcontracts. These subcontracts include research and development of 5 kW to over 1 MW wind systems for a variety of applications.

The Program goal for utility-scale, grid-connected wind power systems is to develop proven technology by 2004 that is capable of producing electricity at a cost of \$0.03/kWh at good wind sites with 6.7 m/s (15 MPH) average wind speed measured at 10 m height with low cost financing. This cost of energy target includes all turbine parts, land lease, and balance of station costs for a 50 MW wind power plant project located near power transmission lines. For the DOE small turbine development projects, the cost goal is to significantly reduce the cost of energy from machines with peak power ratings from 5 to 50 kW. Specific machine goals depend on the type of turbine and the planned operating environment and application requirements.

Subcontracts to develop and test next-generation turbines are in place with Enron Wind Corporation in Tehachapi, California, and the Wind Turbine Company in Belleview, Washington. Each company will cost-share about 30% of their $20 million contracts.

The Wind Turbine Company machine has a unique down-wind rotor design with individually hinged blades. A sub-scale proof-of-concept turbine was installed at the NWTC and has been undergoing testing since April 2000.

Enron's new variable-speed, 1.5 MW turbine incorporates advanced electronics and aerodynamics that capture significantly more energy than constant speed wind turbines at a lower cost. While constant speed rotors must be designed to resist high loads when subjected to wind gusts, Enron's variable speed PowerMax system enables the loads from the gusts to be absorbed and converted to electric power. Test results show that the 1.5 MW turbine met and exceeded its power curve projections, and it generates high quality power. In addition, acoustic noise tests performed by an outside contractor report that the machine is the quietest in its class. Enron's 1.5 MW turbine will be the first of its size class to be produced commercially in the United States. By the end of 2001, Enron expects to have installed 350 of these machines in domestic projects.

Four companies have been selected under the DOE program to develop smaller turbines for both grid-connected and off-grid power generation. The four companies include: Southwest Windpower in Flagstaff, Arizona, for a 6 kW turbine (the design was acquired from World Power Technologies, Inc.); the Atlantic Orient Corporation in Norwich, Vermont, for an 8 kW turbine (acquired from WindLite Company) and for improvement of their 50 kW machine; and Bergey Windpower from Norman, Oklahoma, for a 50-kW turbine; and Northern Power Systems in Moretown Vermont for a 100 kW turbine. The Northern Power Systems turbine is being developed under a cooperative program between NASA, the National Science Foundation, and DOE. This machine is being designed for use in the frigid environments of northern Alaska and Antarctica. The unique turbine design was recognized by the R&D Magazine as one of the top three of the best 100 new products chosen for their "technological significance."

6.3 Cooperative Research and Testing

This research activity includes a wide range of support for industry, verification of advanced turbine performance in field tests, utility applications analysis, and support for the development of standards and turbine certification testing. Grants were recently awarded to industry, electric utilities, and state energy offices to encourage development of wind power in a variety of applications in projects in ten states.

The wind Turbine Verification Project (TVP) is a continuing collaborative effort of DOE, EPRI, and host utilities and operators. The TVP, started in 1992, currently supports seven U.S. wind projects. The projects include 86 turbines ranging in size from 500 kW to 1.65 MW operating in six states with different site characteristics. A similar project conducted by NREL involves assessing the performance and reliability of small turbines with less than 100 kW output. Additional information on the turbine verification projects, including specific results from each project, is available from EPRI at http://www.epri.com.

The NWTC works closely with the IEA to develop recommended practices, and with the International Electrotechnical Commission (IEC) to develop appropriate international standards and testing procedures. In addition, the NWTC is now an accredited testing laboratory for certification of wind turbines for international markets. Although there are currently no domestic requirements for turbine certification in the United States, the NWTC is also accredited by the American Association of Laboratory Accreditation for conducting wind turbine power performance, structures, and noise certification testing. The certification test results from NWTC can be used by the U.S. certification agent, Underwriters Laboratory (UL), or by others, as the basis for certifying the designs of U.S. industries' machines. UL has completed, or is in the process of certifying, the design of the Enron 1.5 MW, the Southwest Windpower 400 W, the Atlantic Orient 50 kW, and the Northern Power 100 kW turbines.

7. CONCLUSIONS

The use of wind energy is growing in the United States at an unprecedented rate, and this trend is expected to continue. There are many interrelated reasons for this growth. The cost of wind energy has declined to less than $0.04/kWh in some applications. New turbine technology will permit the costs to be reduced further for both small and large machines, opening vast new market opportunities. Market expansion is also being stimulated by a wide range of financial incentives available at Federal, state, and local levels. Continuation of these incentives is expected and is considered crucial to continue acceleration of the adoption of wind energy as a viable electric power generation technology.

8. CREDIT TO CONTRIBUTOR

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